The inertial time

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Abstract

In this article we introduced a new universal constant to explain the saturation current of a photoelectric cell . One consequence is that the Universe must be expanding.

Key Words: Inertial time, density of energy, density of power, negative pressure of vacuum.

1)Introduction :

The interpretation of the photoelectric effect (Electrical circuit formed by a photoelectric cell, a direct current source, a galvanometer for measuring current and a source of monochromatic radiation) has been well known for a century [1].

According to Planck-Einstein-Millikan the energy absorbed by an atom from a metal surface (the anticathode for the photoelectric effect experiment) to eject an electron is as follows [2]:

$$E = h.\nu \qquad (1)$$

where : $h = 6.62\ 10^{-34}\ J.s$: Planck constant ;

ν : frequency of the incident radiation.

According to restraint relativity we can associate to every corpuscle with an energy E an inertia $\xi = \frac{m}{\sqrt{1-\frac{v^2}{c^2}}}$ as :

$$E = \xi.c^2 \qquad (2)$$

where : $c = 3\ 10^{8}\ m.s^{-1}$: relativity constant ;

If we increase the voltage across the photocell to accelerate the electrons ejected from the anticathode, the current in the electrical circuit increases and reaches a saturation value regardless of the accelerator potential across the cell. This saturation current increases with the frequency of the incident radiation and with the intensity of the radiation.

The question asked is why we reach a saturation current? . Theoretically with the assertion that the exchange of energy between electrons and photons happens instantaneously - as already commonly admitted - if we increase the accelerating voltage we can extract more electrons and nothing stops this phenomenon than destroying the circuit by heating due to its internal resistance. The real phenomenon is quite another thing: a saturation current is reached whatever the accelerating voltage applied. The discontinuous exchange of energy is not the reason for reaching a saturation current. The initial flaw is to assume that the exchange of energy happens instantaneously.

If we assume that the absorption of the incident photon takes place with a certain non-zero duration, the current saturation is well explained. Indeed, if each incident photon spends a certain time to be absorbed by an atom on the cathode surface and eject an electron then the next photon must wait for this time to interact with the same atom if not it is lost in space by reflections. If all the atoms of the cathode surface are in interaction with the incident radiation i.e. the number of incident photons covers the number of atoms of the metal surface of the cathode which can interact with these photons then the intensity of the current can no longer increase since it is necessary to wait a certain duration to enter into interaction again with the atoms of the surface and then the surplus of incident photons during this duration will be lost by reflections: the increase in the accelerating voltage will have no effect on the saturation current even if it is believed that the duration of travel of the electron between electrodes has been made almost zero. The interaction time between photon and electron, however small it may be, modulates the current and stabilizes it at a constant value for a constant light intensity: this phenomenon is also a quantum phenomenon which is not perceived and analysed deeply.

We can oppose the idea presented at the beginning by saying that the lifetime of the excited atoms of the cathode plate is that which modulates the current: the answer is no since there are always excited atoms without the effect of incident light and this excitation is due only to the effect of the ambient temperature of this plate. The worst case - or the best case - is to approximate the duration of excitation of the cathode atoms to that associated with the inertia of the photon.

It is time to assume that a photon cannot give up all of its energy instantly: it must be associated with a certain time which is specific to the photon itself and which characterizes this inertia of exchange.

For a given photon we can associate it with an inertial time τ such that:

$$E = h.\upsilon = \xi.c^2 = \alpha_0.\tau \qquad (3)$$

where : α_0 : a new Universal constant of Nature.

The origin of the name inertial time is well explained by equation (3).

In terms of angular frequency$\omega = 2\pi\upsilon$ the energy of the photon can be expressed as follows:

$$E = \hbar.\omega \qquad (4)$$

where : $\hbar = \frac{h}{2\pi} = 1.054\ 10^{-34}\ J.s$: reduced Planck constant;

$\omega = \omega_0 \pm \Delta\omega$: frequency of incident radiation with some uncertainty.

We have also :

$$\Delta E = \hbar.\Delta\omega = \alpha_0.\Delta\tau \qquad (5)$$

The uncertainty on the inertial time can be roughly assimilated to the lifetime of the excited state of the atoms that are the source of the incident light if it is obtained in this way (by excitation of a gas for example) and then we have:

$$\Delta\tau = \frac{1}{\Delta\omega} \approx lifetime\ of\ excited\ state \qquad (6)$$

It only remains for us to specify how to determine the new universal constant α_0 .

2) The experience of the photoelectric effect:

The discontinuous nature of the energy carried by radiation combined with the idea of instantaneous absorption of photons by a photoelectric cell theoretically leads to a current which increases as the number of incident photons increases without reaching a saturation value in contradiction with the experimental fact which is that a saturation value is indeed reached. If we change our idea which is that the absorption of photons by the cell will hold for a certain time, then the saturation current is well explained which can lead us to reinterpret the experience of the photoelectric effect and predict the existence of a new universal constant having the dimension of energy per unit of time.

The minimum kinetic energy of an electron ejected from the photocathode is [3]:

$$E_{cin} = E - W \qquad (7)$$

where : E: energy supplied by incident radiation;

W: the work of extracting an electron from the cathode metal of the cell.

Let's have "$-V$" the voltage applied to the terminals of the cell using an adjustable direct current generator. Let's have I the current measured in the circuit using a galvanometer in series with the cell.

-If $e.V > E_{cin}$ than "$-V$" is the potential that prevents all ejected electrons from reaching the collection electrode;

-If $e.V \leq E_{cin}$ then the stripped electrons can reach the negatively charged electrode and there will be a current in the circuit;

with: $e = 1.6\ 10^{-19}\ Coulomb$: elementary electric charge .

We can therefore measure the current as a function of the braking potential V and if V_0 is the potential for which the current falls to zero, we will have:

$$V_0 = \frac{h}{e}.\nu - \frac{W}{e} \qquad (8)$$

By drawing the curve of the retarding potential V_0 according to the frequency of the incident radiation Millikan was able to deduce the linearity coefficient $\frac{h}{e}$ and the constant of the cathode material $\frac{W}{e}$.

If we continue to increase the braking potential V the current will increase in the circuit until it reaches for the first time a saturation value I_{max}.In other words the potential V becomes an accelerating potential of the ejected electrons. Experience shows that this potential is positive and does not exceed too much $30\ volts$.

If P is the incident light power the number of photons hitting the cathode surface over time Δt is :

$$N = \frac{P.\Delta t}{h.\nu} \qquad (9)$$

The number of removed electrons is:

$$n = \frac{I_{max}.\Delta t}{e} \qquad (10)$$

It is assumed that the photocell has an efficiency η constant and independent of frequency. This efficiency is equal to the ratio of the number of absorbed photons and the actual number hitting the cathode surface:

$$\eta = \frac{n}{N} = \frac{I_{max}.h.\nu}{P.e} \qquad (11)$$

We choose $\Delta t = \tau$, the power $P = N\alpha_0$ and so from (11) :

$$N = \frac{I_{max}.h.\nu}{\alpha_0.e.\eta} \qquad (12)$$

It is clear that if we double the light power, the saturation current will also be double and this is what is observed experimentally. If we know how to determine exactly the number of incident photons for the duration τ we can draw the curve $N = f(I_{max})$ and determine the corresponding linearity coefficient which according to (12) contains the constant α_0 , but this duration is unknown and then we will go around in circles.

We can get a rough idea of the value of the new universal constant by giving an estimate of the interaction time.

A typical photocell [4] has an efficiency $\sim 10^{-3}$. The distance between its electrodes is of the order of $1\ cm$. The photoelectric effect itself is of the order of a volt in the visible range corresponding to the frequency interval $[4.3 - 7.5]x10^{14}\ Hertz$. The ratio $\frac{W}{e}$ is also of the same order either between$[2 - 5]volt$.

The minimum electron ejection speed with near ultraviolet light is according to (7):

$$v_{min} = \sqrt{\frac{2(h\nu - W)}{m}} = \sqrt{\frac{2(6.62\ 10^{-34}x7.5\ 10^{14} - 2x1.6\ 10^{-19})}{9.1\ 10^{-31}}} = 0.62\ 10^{6}\ m.s^{-1}$$

The accelerator potential is low in practice, so the influence of the acceleration on the speed of arrival at the collection electrode is minimal: the speed remains practically constant.

The electron's travel time is:

$$t \sim \frac{1cm}{0.62\ 10^{6} m.s^{-1}} \sim 10^{-7}\ second$$

Discussion:

-If the duration of interaction of the photon with the atom of the plate is greater than the duration of travel of the electron then it will modulate the intensity of the current but it must not be too great compared to the duration of trip if not the current will pass by perceptible cascades which is not the case: the solution is that the interaction time is an integer multiple of the trip time and this integer is small.

-If the interaction time of the photon is lower compared to the travel time then we can make the interaction time as small so as to extract off a few electrons which by their successive sums correspond to the maximum intensity but in this case one is in contradiction that the extracting of electrons is in its optimum: to remove this contradiction the solution is that the travel time is an integer multiple of the interaction time and this integer is small.

Thus the interaction time of the photon is an integer multiple of $10^{-7}\ second$ or $10^{-7} second$ is an integer multiple of the interaction time and in all cases this integer is small.

In our case, the light close to blue we have:

$$\alpha_0 = \frac{h\nu}{\tau} \sim \frac{6.62\ 10^{-34}x7{,}5\ 10^{14}}{10^{-7}} \sim 50\ 10^{-13}\ Watts$$: To multiply or divide by a small integer.

3) The black body radiation experience:

If from Planck's hypothesis that the exchange of energy between the electrons of the atoms of the wall of a black body assimilated to harmonic oscillators takes place by integer multiple quantities of a certain elementary quantity $\varepsilon = h\nu$ where ν is the frequency of the oscillator, Planck was able to determine the values of its constant h and that of Boltzmann k by referring only to two experiments that of F. Kurlbaum and that of Wien [5] then we can do the same thing as him to determine the new universal constant α_0 .

We turn back to the year 1900 and we will follow Planck's method step by step with of course considering the modern theoretical developments of the theory of black body radiation to shorten this path.

Let therefore having a black body cavity in thermal equilibrium at a temperature T and in which a small hole has been drilled to measure the power and radiant energy.

The average of photons at frequency ν in thermal equilibrium in the cavity is [6]:

$$n = \frac{1}{\exp\left(\frac{h.\nu}{k.T}\right)-1} \quad (13)$$

The average photon energy at this frequency is:

$$E_\nu = nh\nu = \frac{h\nu}{\exp\left(\frac{h.\nu}{k.T}\right)-1} \quad (14)$$

The average of the power of the photons at this frequency is:

$$P_\nu = n.\alpha_0 = \frac{\alpha_0}{\exp\left(\frac{h.\nu}{k.T}\right)-1} \quad (15)$$

The number of modes δM for polarized electromagnetic waves contained in the volume V of the cavity and in the frequency interval $\delta\nu$ is :

$$\delta M = 8\pi.V.\frac{\nu^2}{c^3}.\delta\nu \quad (16)$$

The energy contained in the frequency interval $\delta\nu$ is :

$$\delta U = E_\nu.\delta M = 8\pi.V.\frac{\nu^2}{c^3}.\frac{h\nu}{\exp\left(\frac{h.\nu}{k.T}\right)-1}.\delta\nu \quad (17)$$

The power contained in the frequency interval $\delta\nu$ is :

$$\delta P = P_\nu.\delta M = 8\pi.V.\frac{\nu^2}{c^3}.\frac{\alpha_0}{\exp\left(\frac{h.\nu}{k.T}\right)-1}.\delta\nu \quad (18)$$

Energy density per frequency interval $\delta\nu$ is (Planck's law):

$$dU = \frac{\delta U}{V} = \frac{8\pi.h.\nu^3}{c^3}.\frac{1}{\exp\left(\frac{h.\nu}{k.T}\right)-1}.d\nu = u_\nu.d\nu \quad (19)$$

Power density per frequency interval $\delta\nu$ is :

$$dP = \frac{\delta P}{V} = 8\pi.\frac{\nu^2}{c^3}.\frac{\alpha_0}{\exp\left(\frac{h.\nu}{k.T}\right)-1}.d\nu = p_\nu.d\nu \quad (20)$$

Integrate (19) for all frequencies (Stefan-Boltzmann law):

$$U = b.T^4 \quad (21)$$

with : $b = \frac{8.\pi^5.k^4}{15.h^3.c^3}$ having the size of $[J.m^{-3}.K^{-4}]$

Integrate (20) for all frequencies:

$$P = \frac{30.\zeta(3).b.\alpha_0}{\pi^4.k}.T^3 \quad (22)$$

with : $\zeta(3) = 1.202056 \ldots$ Zeta function or Riemann function.

P having the size of $[Watt.m^{-3}]$.

From the experimental measurements of F. Kurlbaum and for $T = 1K$, Planck deduced the following value by eliminating the time by dividing the experimental value by $\frac{c}{4}$. F. Kurlbaum's time base in his measurements is the second as explained by Planck in his article [5]:

“§11. The values of both universal constants h and k may be calculated rather precisely with the aid of available measurements. F. Kurlbaum, designating the total energy radiating into air from 1 sq cm of a black body at temperature t ◦ C in 1 sec by S_t, found that:

$$S_{100}-S_0=0.0731\ \frac{Watt}{cm^2}=7.31\ 10^5\ \frac{erg}{cm^2.sec}\text{ ”}$$

Planck found that:

$$\frac{k^4}{h^3} = 1.1682\ 10^{15}\ cgs\ unities \qquad (23)$$

From Wien's law of displacement and for $T = 1K$ Planck deduced that:

$$\frac{h}{k} = 4.866\ 10^{-11}\ \ cgs\ unities \qquad (24)$$

The power density of a black body is according to (20):

$$p_\nu = 8\pi.\frac{\nu^2}{c^3}.\frac{\alpha_0}{\exp\left(\frac{h.\nu}{k.T}\right)-1} \qquad (25)$$

Replace $u = \frac{h\nu}{kT}$ in (25) :

$$p_\nu = \frac{8\pi.k^2.T^2.\alpha_0}{h^2.c^3}.\frac{u^2}{\exp(u)-1} \qquad (26)$$

The maximum power density is obtained when $\frac{dp_\nu}{d\nu} = \frac{dp_\nu}{du} = 0$. We deduce from (26) that :

$$u - 2 = W(-2.e^{-2}) = W(-0.27) \approx -0.406 \qquad (27)$$

Where : W : Lambert's function to be solved graphically.

From (27) it comes that:

$$\nu_{max} \approx 1.594\ \frac{k}{h}.T \qquad (28)$$

The frequency ν_{max} for $T = 1K$ can be expressed by reference to a base value as follows:

$$\nu_{max} = \nu_0 = f.\sqrt{\frac{\alpha_0}{h}} \qquad (29)$$

where : f : a modulation factor that we will be looking for.

We choose a time base h_0 so that the maximum algebraic value for the volume power density is equal to the maximum volume energy density divided by this time base:

$$p_{\nu-max} = \frac{u_{\nu-max}}{h_0} \qquad (30)$$

Where the time base h_0 is defined as follows:

$$h_0 = \frac{1}{\nu_0} = \frac{1}{f}.\sqrt{\frac{h}{\alpha_0}} \qquad (31)$$

The maximum volume energy density is given by Wien's law [7]:

$$\nu_{max}T^{-1} = 5.879\ 10^{10}\ Hz.K^{-1} \qquad (32)$$

Planck has already solved the system of equations (23) & (24). The resolution of the rest is similar.

For convenience we keep the same values found by Planck:

$h = 6.55\ 10^{-27}\ erg.second$

$k = 1.346\ 10^{-16}\ erg.K^{-1}$

From (28) & (29) & for $T = 1K$ we get :

$$1.594\ \frac{k}{h} = f.\sqrt{\frac{\alpha_0}{h}} \qquad (33)$$

The total power density corresponds to the total energy density by reference to the same time base "h_0" (in algebraic value):

$$P_{max} = \frac{U_{max}}{h_0} = \frac{b.T^4}{h_0} \qquad (34)$$

Replace (21) & (22) in (34) & take $T = 1K$:

$$\frac{30.\zeta(3).\alpha_0}{\pi^4.k} = f.\sqrt{\frac{\alpha_0}{h}} \qquad (35)$$

By eliminating $f.\sqrt{\frac{\alpha_0}{h}}$ between the two equations (33) and (35) we will have:

$$\frac{30.\zeta(3).\alpha_0}{\pi^4.k} = 1.594\ \frac{k}{h} \qquad (36)$$

Which gives in cgs units:

$$\alpha_0 = 1.594\frac{k^2.\pi^4}{h.30.\zeta(3)} = 1.594x\frac{(1.346\ 10^{-16})^2.\pi^4}{6.55\ 10^{-27}x30x1.202056} = 1.191\ 10^{-5}erg.s^{-1}$$

Either in MKS units:

$\alpha_0 = 1.191\ 10^{-12}\ Watt$

From equations (32) & (29) & for $T = 1K$ we get:

$$\nu_{max} = 5.879\ 10^{10} = f.\sqrt{\frac{\alpha_0}{h}} = f.\sqrt{\frac{1.191\ 10^{-5}}{6.55\ 10^{-27}}} = fx0.4264\ 10^{11}$$

That is:

$f = 1.3787$ a dimensionless factor.

From (31) we deduce:

-The time base:

$$h_0 = \frac{1}{f}.\sqrt{\frac{h}{\alpha_0}} = \frac{1}{1,3787}.\sqrt{\frac{6,55\ 10^{-27}}{1,191\ 10^{-5}}} = 1.701\ 10^{-11}\ second$$

-A reference frequency:

$\nu_0 = \frac{1}{h_0} = 0.588\ 10^{11}\ Hz$

-A reference energy:

$\varepsilon_0 = h.\nu_0 = 6.55\ 10^{-27} x 0.588\ 10^{11} = 3.85\ 10^{-16}\ erg$

-A reference length:

$L_0 = c.h_0 = 3\ 10^{10} x 1.701\ 10^{-11} = 0.5103\ centimeter$

-A reference mass:

$M_0 = \frac{\varepsilon_0}{c^2} = \frac{3.85\ 10^{-16}}{9\ 10^{20}} = 0.427\ 10^{-36}\ gram$

From (28) and (29) we define what a Kelvin degree is:

$$1K = \frac{1}{1,594}.\nu_0.\frac{h}{k} = \frac{f}{1,594}.\sqrt{\frac{\alpha_0}{h}}.\frac{h}{k} = \frac{1.3787}{1.594}.\frac{1}{k}.\sqrt{\alpha_0.h} = 0.865x\frac{1}{k}.\sqrt{\alpha_0.h}$$

-Energy density for a black body:

$U = b.T^4$ with $b = \frac{8.\pi^5.k^4}{15.h^3.c^3} \approx 7.56\ 10^{-16}\ J.m^{-3}.K^{-4}$

-Power density for a black body:

$P = \delta.T^3$ with $\delta = \frac{30.\zeta(3).b.\alpha_0}{\pi^4.k} = \frac{30x1.202056x7.56\ 10^{-16}1.191\ 10^{-12}}{\pi^4 x1.346\ 10^{-23}} = 2.476\ 10^{-5}\ Watt.m^{-3}.K^{-3}$

- Also define a mechanical impedance of the vacuum:

$a = \frac{\alpha_0}{c^2} = 0.1323\ 10^{-25}\ g.s^{-1}$

Which means that the vacuum is full of energy and can exchange energy with moving systems. But this energy exchange is carried out theoretically by viscous friction of coefficient "a" which is in contradiction with the initial hypothesis for inertial motion which is assumed to be frictionless: the only solution to overcome this contradiction is to associate a negative power density with the vacuum to eliminate any viscosity effect. A negative power density means that the energy density of the vacuum is always decreasing i.e. that space-time and therefore the entire Universe is expanding, a result confirmed by modern cosmology. Power density is nothing but the variation of energy density with respect to time and it is also a negative pressure which varies with time: this to explain our previous conclusion. Associating a negative power density with a vacuum is theoretically equivalent to associating a negative temperature with a vacuum, which does not pose a problem for the energy density of the vacuum since the latter always remains positive given that it is propositional to the fourth power of temperature.

Thus defining an immutable and empty inertia frame of reference according to Newtonian or Minkowskian theory is not physically possible: an inertia frame of reference must be full of energy, expanding and having a negative pressure as a function of time.

Note also if we determine the Planck constant h by the experiment of the photoelectric effect and the Boltzmann constant k taken as being the ratio of the ideal gas constant and the Avogadro number, we can determine the value of the speed of light using the measurements of F. Kurlbaum. Wien's law of displacement will be used to determine the new constant α_0.

Equation (3) means that the inertia of any system is in time.

Associating a mechanical impedance with a vacuum and combined with the notion of wave-particle duality can lead us to unify all the forces of Nature into a single force including gravitation.

3)Conclusion:

Thus we realized Maxwell's wish to have a system of units built from atomic vibrations:

"If we wish to obtain standards of length, time and mass which shall be absolutely permanent, we must seek them not in the dimensions, or motion or the mass of our planet, but in the wavelength, the period of vibration, and absolute mass of these imperishable and unalterable and perfectly similar molecules. **"**
J.C. Maxwell (1870)

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